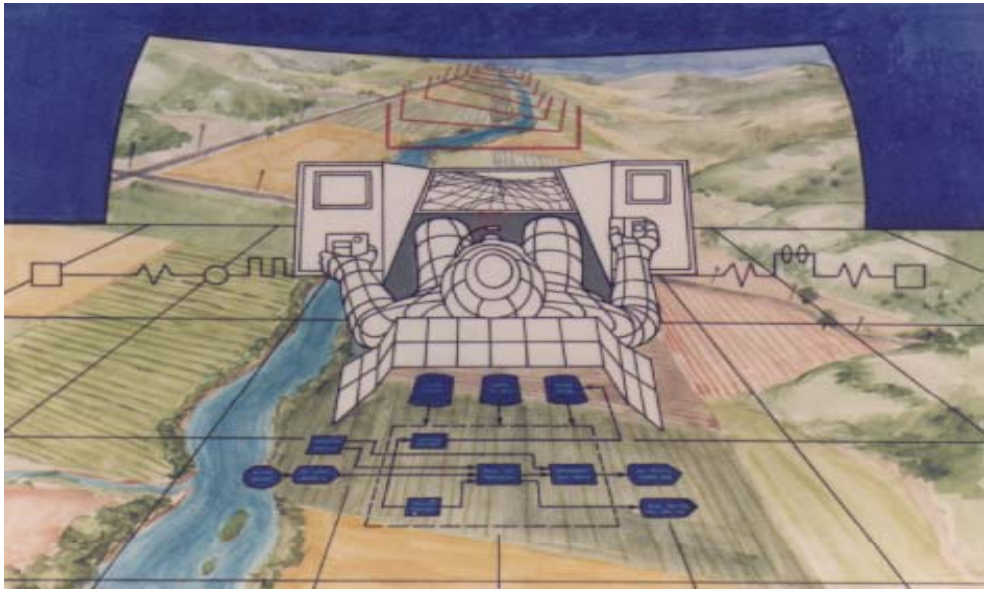
System-Wide Accident Prevention: Human Performance Modeling



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Outline of Topics

- **Problem, Approach and Goal**
  - Errors and accidents in Aviation
  - Model development plan
- **Developing Cognitive Modeling Tools for System Design**
  - Overview of 5 modeling frameworks
  - Application to taxi-navigation problem
  - Application to approach and landing operations with and without augmented displays
- **Developing an Activity Tracking Model for Error Detection and Analysis**
  - Overview of CATS (Crew Activity Tracking System)
  - Application to flight test data

Problem, Approach and Goal

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Problem

- Accident precursors are complex interaction of latent error in a system design or procedure (and dynamic interaction of design, human operation and environment)
- Difficult to observe rare error and error precursors in aviation environment ($1x10^{-n}$)
- Design cycle (design, build, evaluate, field, revise) is difficult, expensive, and time-consuming

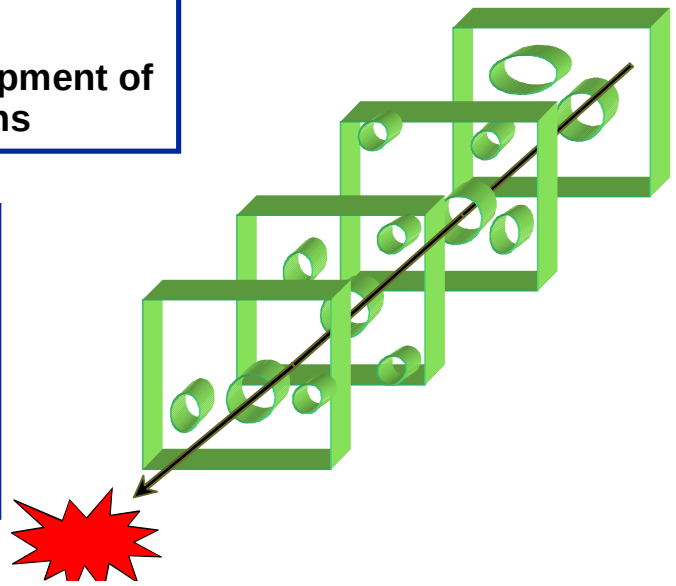
Approach

- Identify scenarios with high probability of human error
- Identify/model precursors to errors
- Assess technological and procedural solutions via development of computational models of scenarios and candidate solutions

Goal

Develop modeling capability to:

- Assess technological and procedural solutions via development of computational models of scenarios and candidate solutions
- Test potential mitigation strategies



Accidents/ Incidents
Error/ Error precursors

Reason 1990

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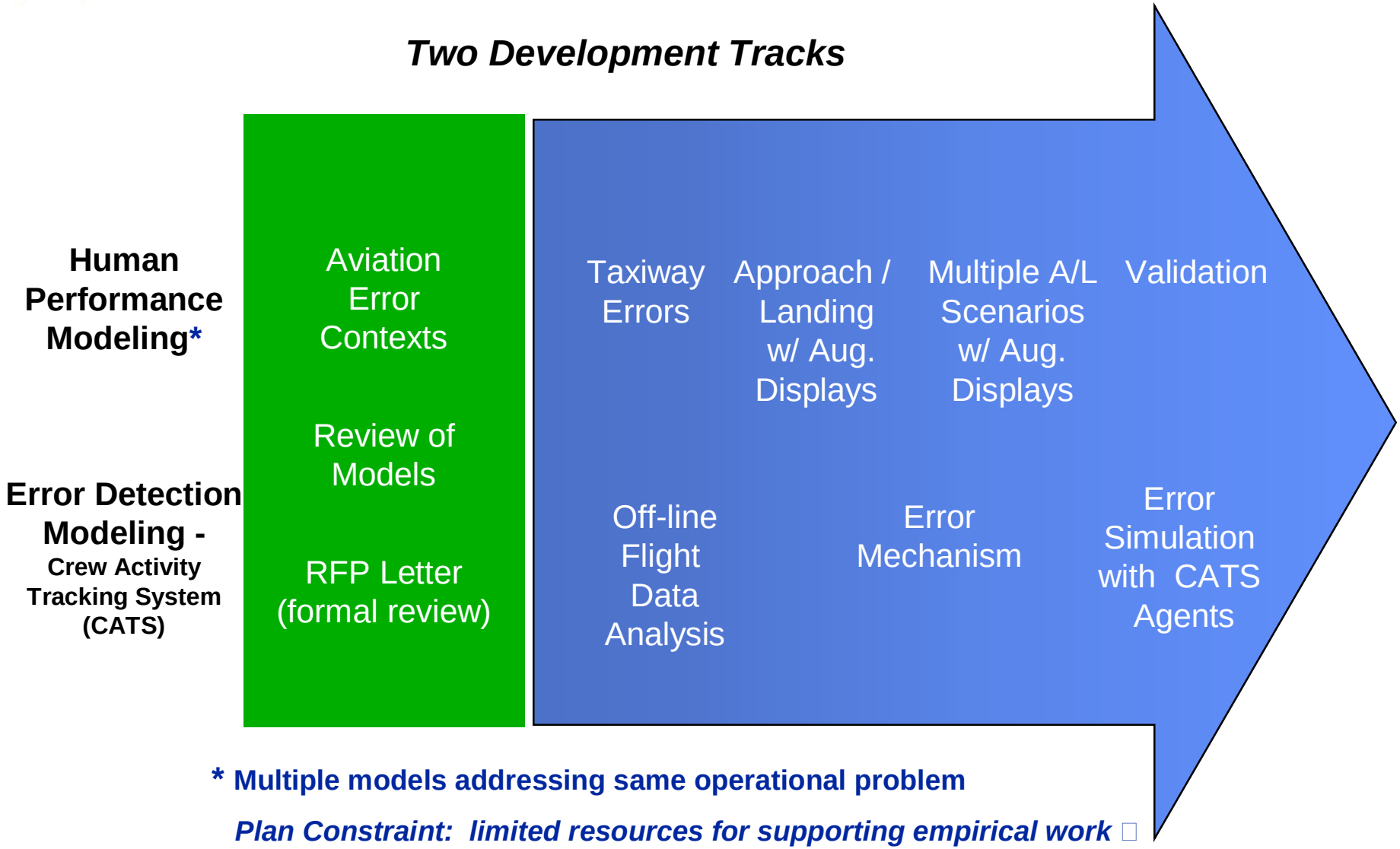
Plan FY00-FY04

Two Development Tracks



*** Multiple models addressing same operational problem**

Plan Constraint: limited resources for supporting empirical work

Selected Modeling Frameworks

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Characteristics of selected models

- Operator level, cognitively oriented
- Comprehensive, mature and validated systems
- Integrative frameworks facilitating fast-time simulation
- Output is generative, stochastic, context sensitive

Model	Type	Research Team	Demonstrated Sources of Pilot Error
ACT-R/PM	Low-level Cognitive with Statistical Environment Representation	Mike Byrne Rice University Alex Kirlik University of Illinois	* Time pressure * Misplaced expectations * Memory retrieval problems
Air MIDAS	Integrative Multi-component Cognitive	Kevin Corker Brian Gore Eromi Guneratne Amit Jadhav & Savita Verma San Jose State University	* Workload * Memory Interference * Misperception
A-SA	Component Model of Attention & Situational Awareness	Chris Wickens Jason McCarley Lisa Thomas University of Illinois	* Misplaced attention * Lowered SA
D-OMAR	Integrative Multi-component Cognitive	Stephen Deutsch Richard Pew BBN Technologies	* Communications errors * Interruption & distraction * Misplaced expectation
IMPRINT/ ACT-R	Hybrid: Task Network with Low-level Cognitive	Rick Archer Micro Analysis and Design, Inc. Christian Lebiere, Dan Schunk,& Eric Biefeld Carnegie Mellon University	* Time pressure * Perceptual errors * Memory retrieval * Inadequate knowledge

Progressive Implementation Strategy

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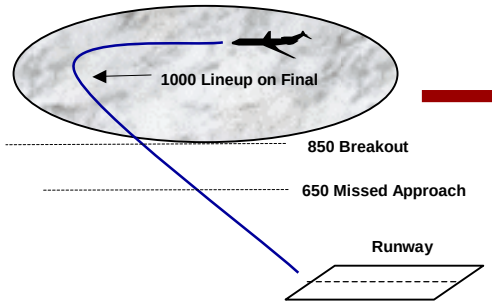
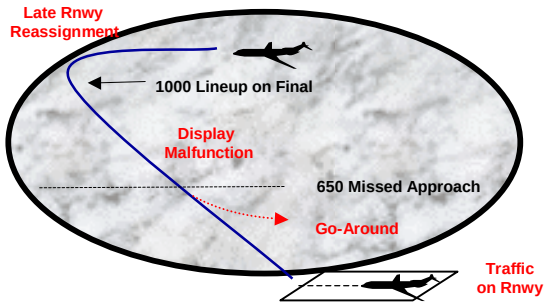
Advancing cognitive models into increasingly complex real-world applications

'01 Modeling
Taxi-Navigation Errors

'02-'03 Modeling
Nominal Approach/Landing
with and without SVS



'03-'04 Modeling
Multiple Off-Nominal
Approach/Landing with and
without SVS



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Taxi Navigation Modeling

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Data Set

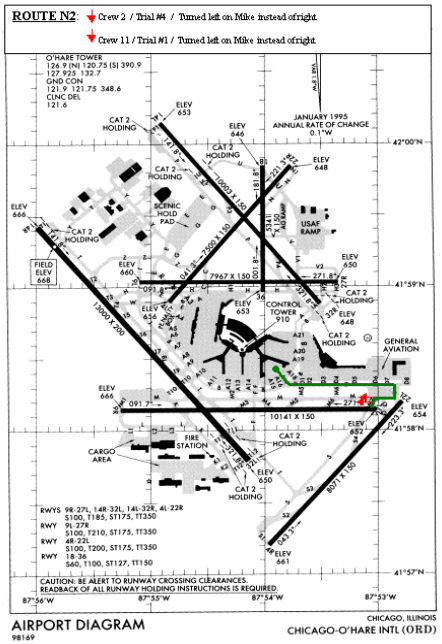
T-NASA Full Mission Simulation

Modeling Problem

Reproduce/Explain
Taxiway Navigation Errors

Scenario Specifications

- **High-fidelity full motion simulation of taxi-to-gate at Chicago-O'Hare**
- **54 trials run by 18 airline crews**
- **9 different cleared routes -- all in low visibility (1000 RVR)**
- **Traffic, hold short, and route changes included in scenarios**
- **12 off-route errors committed by crews and specified to modelers**



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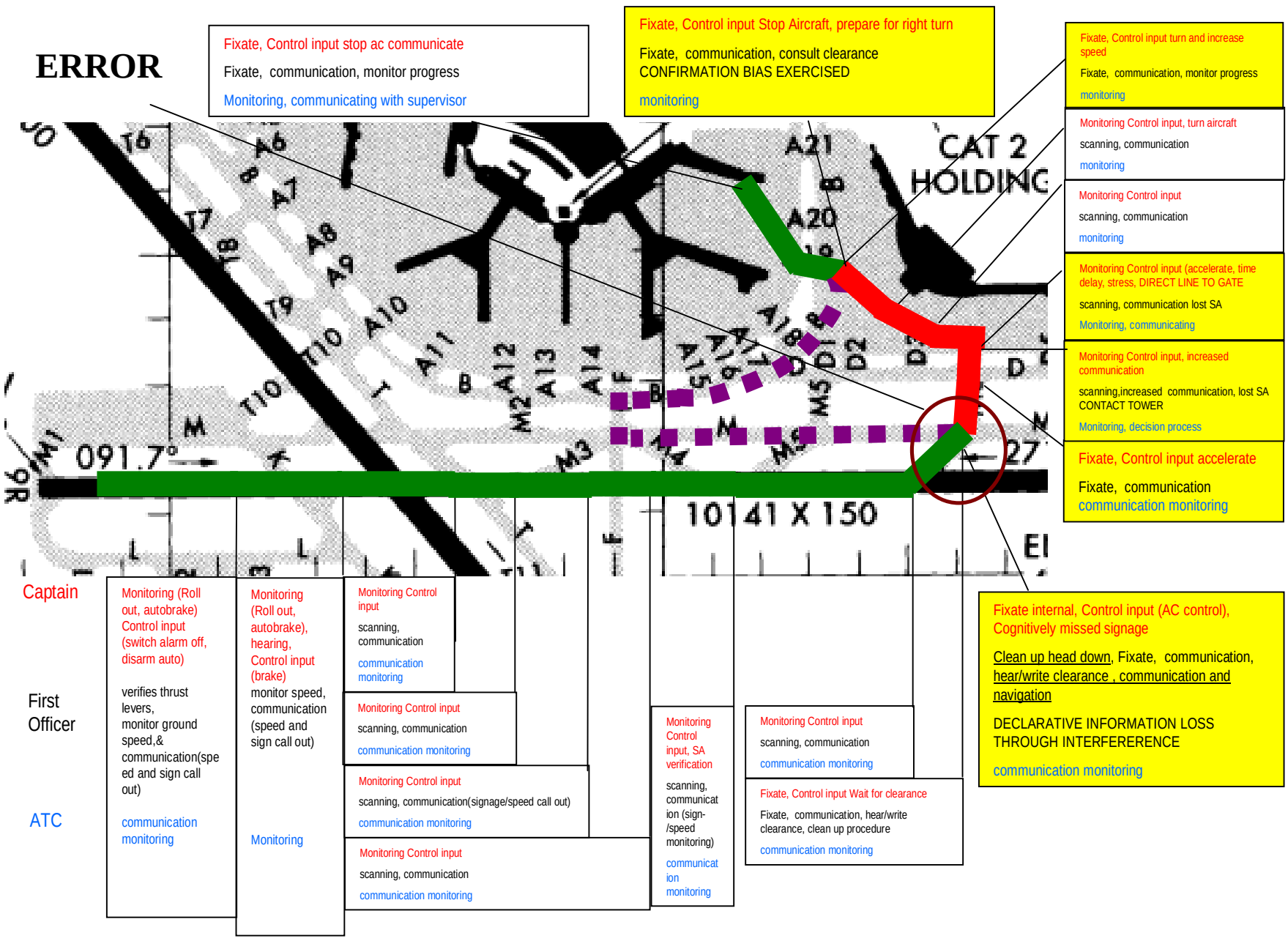
Air MIDAS Simulation of Observed Error



Modeling Nominal Approach & Landing

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Data Set

Part-task Pilot-in-loop Simulation
Performance data and Eye-tracking (3 Subjects)

Other Information Provided Modelers

Detailed Cognitive Task Analysis

Modeling Problem

Develop "Normative" Model of Approach & Landing with and without Augmented Display

Scenarios

Display Configuration		Baseline	Baseline	SVS
Visibility		VMC	IMC	IMC
	Nominal Approach (nominal landing)	*Scenario #1*	*Scenario #4*	*Scenario #7*
	Late Reassignment (side-step & land)	*Scenario #2*		*Scenario #8*
	Missed Approach (go-around)	*Scenario #3*	*Scenario #5*	*Scenario #9*
	Terrain Mismatch (go-around)		*Scenario #6*	*Scenario #10*

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QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

Implementation Plan Status

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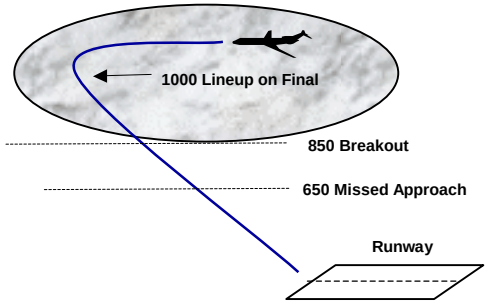
'01 Modeling Taxi-Navigation Errors

- Technical report on context of aviation errors
- Development of 5 models of surface operations
- Workshop 10/18/01

Proof-of-Concept: replication and causal explanation of various observed pilot taxi-navigation errors committed in high-fidelity simulation

'02-'03 Modeling Nominal Approach/Landing with and without SVS

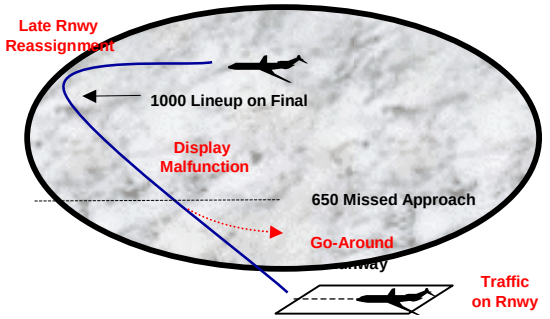
- Cognitive Task Analysis
  - Baseline approach& landing
  - Augmented display approach & landing
- Part-task Pilot-in-loop Simulation
  - Eye-tracking data
  - Display monitoring/ usage data
  - Multiple scenarios (late runway reassignment, system failure, etc.)
- Models of Approach / Landing
  - Initial model development
- Workshop scheduled 3/6/03
- Operator model provided to AvSP ASMM project



Demonstrated: 3 working models of pilot performance during nominal approach/landing: good correlations between simulation outputs and observed pilot eye tracking/visual attention allocation

'03-'04 Modeling Multiple Off-Nominal Approach/Landing with and without SVS

- Models of Approach / Landing
  - Develop advanced models
  - Investigate off-nominal scenarios
  - Identify error susceptibilities
  - Evaluate mitigation strategies
- Model Verification/Validation Approaches
  - Determine "choke points" (e.g., workload, SA at transition points)
  - Cross scenario
  - Cross model
  - Emergent behaviors



Objective: prediction of pilot attentional allocation, decisions, and actions during off-nominal operations with & without SVS

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Crew Activity Tracking System (CATS)

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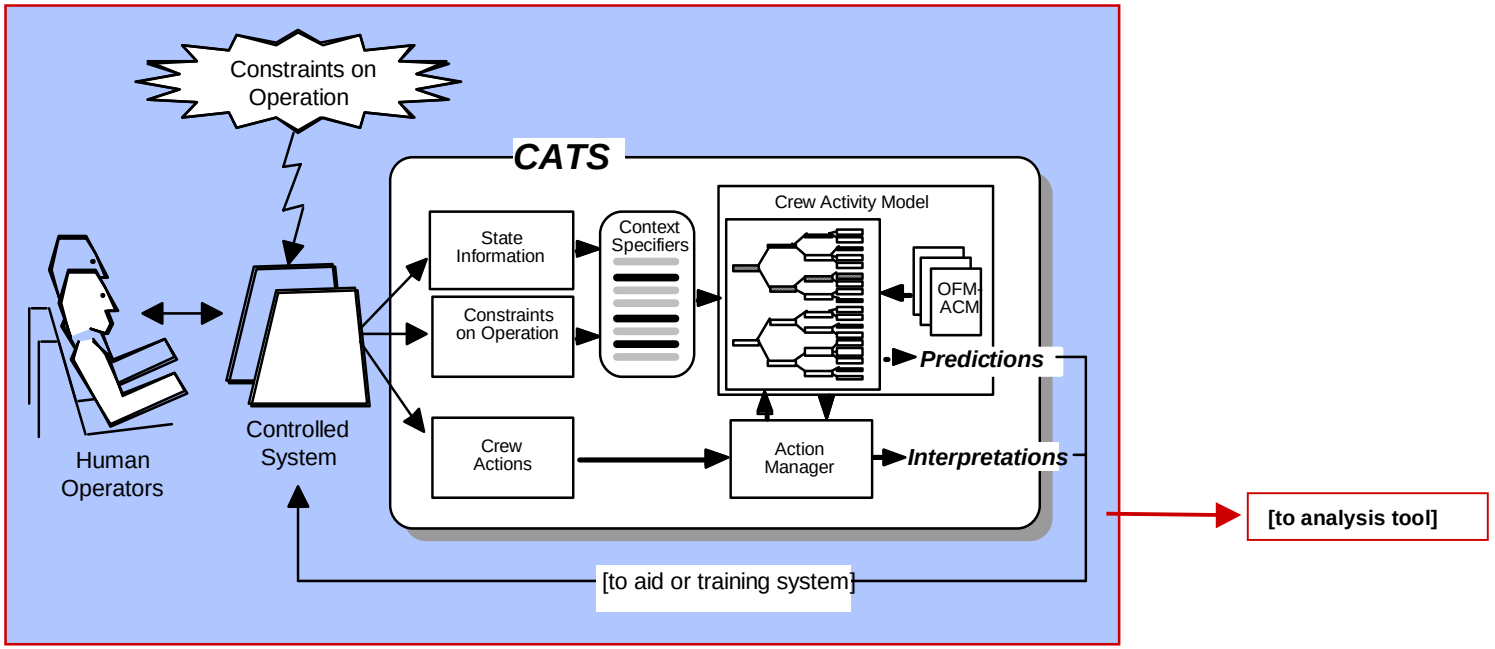
Computerized engineering model of correct task performance to predict operator activities and interpret operator actions



- **Provides context-dependent knowledge about the operator's task that can support tutors, aids, and displays to enhance safety**
- **Supports visualization and analysis of human-automation interaction**

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Detecting Errors from Flight Data

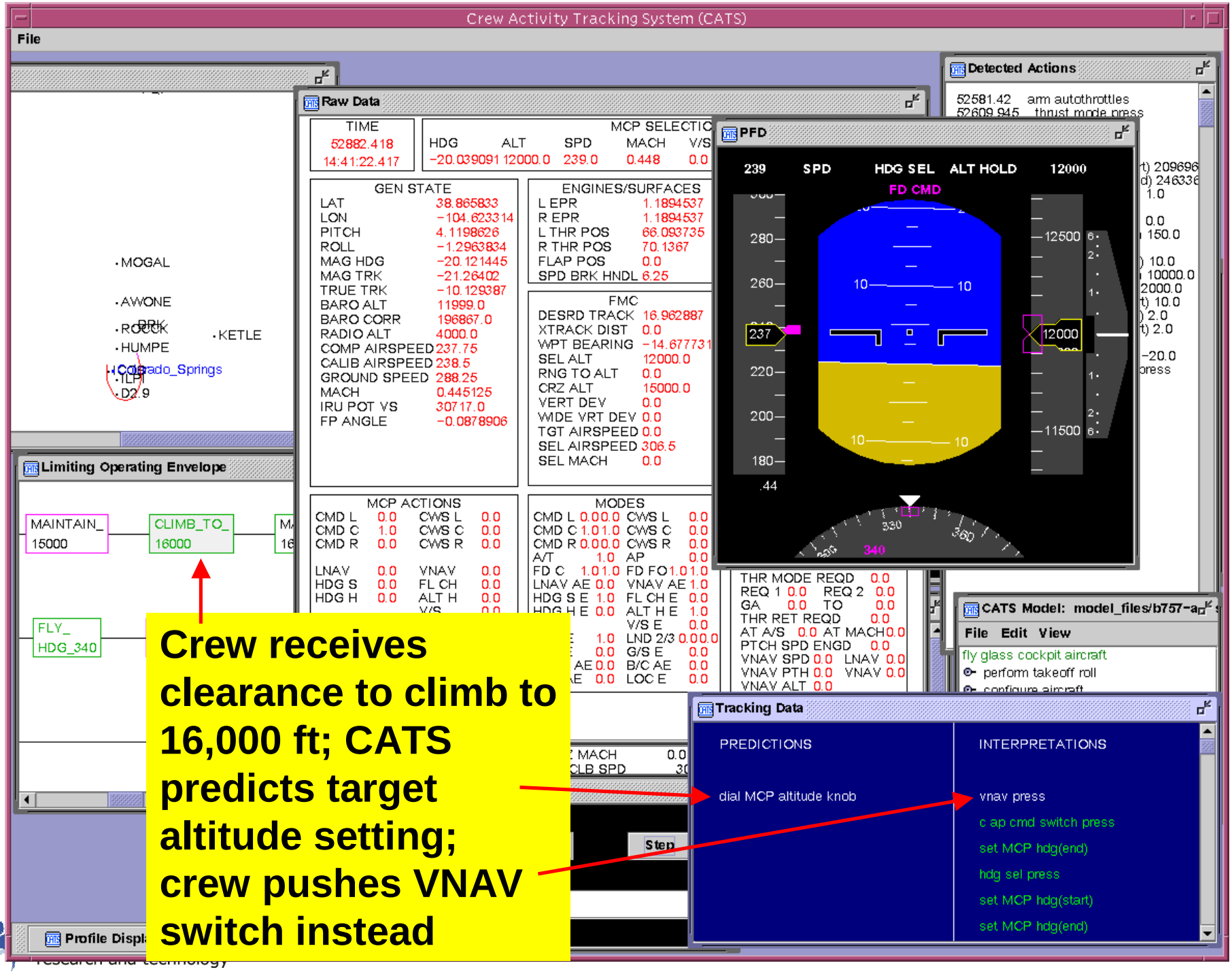
Current research demonstrates how CATS can analyze flight data from the Langley B757 ARIES aircraft to detect procedural errors

Callantine (2001a, 2001b)

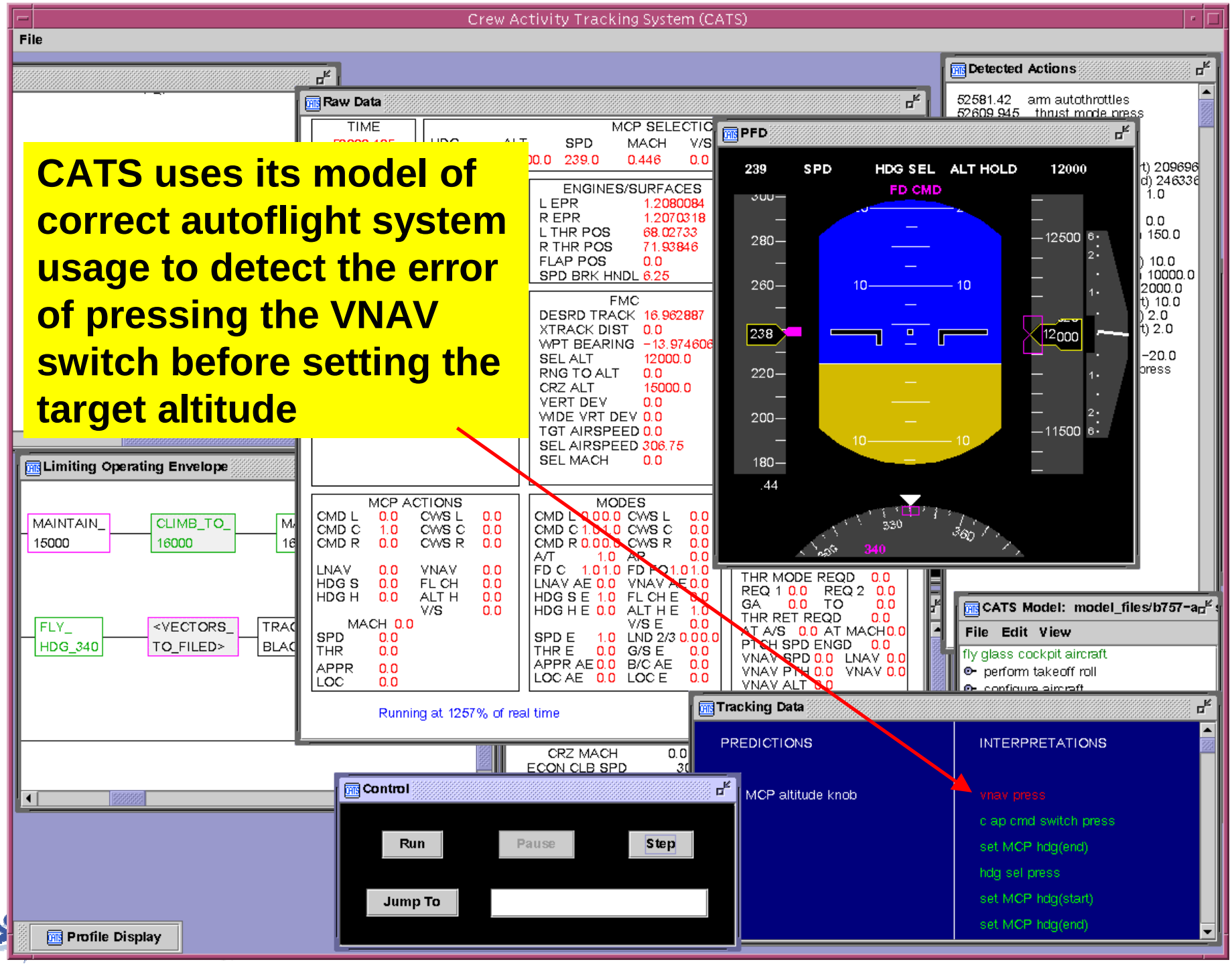
NASA B757-ARIES

On-board Data Acquisition System used to collect flight data

Cockpit observations verified and augmented digital data



Crew receives clearance to climb to 16,000 ft; CATS predicts target altitude setting; crew pushes VNAV switch instead


CATS uses its model of correct autoflight system usage to detect the error of pressing the VNAV switch before setting the target altitude
Crew Activity Tracking System (CATS)
File
Raw Data
Detected Actions
52581.42 arm autothrottles
PFD
239 SPD HDG SEL ALT HOLD 12000
FD CMD
Limiting Operating Envelope
MAINTAIN_ 15000
CLIMB_TO_ 16000
FLY_ HDG_340
<VECTORS_ TO_FILED>
ENGINES/SURFACES
L EPR 1.2080084
R EPR 1.2070318
L THR POS 68.02733
R THR POS 71.93846
FLAP POS 0.0
SPD BRK HNDL 6.25
FMC
DESRD TRACK 16.962887
XTRACK DIST 0.0
WPT BEARING -13.974606
SEL ALT 12000.0
RNG TO ALT 0.0
CRZ ALT 15000.0
VERT DEV 0.0
WIDE VRT DEV 0.0
TGT AIRSPEED 0.0
SEL AIRSPEED 306.75
SEL MACH 0.0
MCP ACTIONS
MODES
Running at 1257% of real time
CRZ MACH 0.0
ECON CLB SPD
CATS Model: model_files/b757-a
File Edit View
fly glass cockpit aircraft
perform takeoff roll
Tracking Data
PREDICTIONS
INTERPRETATIONS
MCP altitude knob
vnav press
c ap cmd switch press
set MCP hdg(end)
hdg sel press
set MCP hdg(start)
set MCP hdg(end)
Control
Run
Pause
Step
Jump To
Profile Display

Summary of CATS Development

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Demonstrated ability to detect pilot error from in-flight data

- Autoflight misusage in approach/landing operations
- Potential for onboard real-time error detection system

Developed CATS framework into autonomous agent model

- Demonstrated agents that function as air traffic controllers capable of handling flow spacing problems in simulation
- Potential for stand-in for human air traffic controllers in large-scale simulations

Extend CATS agent-based models to incorporate error

- Developing process by which nominal agents will make *realistic* errors in fast-time simulation
- Potential to conduct "effects analysis" for a given scenario resulting from introduction of a particular error mechanism

Back-up Material

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Journals, Books, Conference Proceedings

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